Subterranean Biology 45: 17–37 (2023)
doi: 10.3897/subtbiol.45.95845
https://subtbiol.pensoft.net

RESEARCH ARTICLE

A peer-reviewed open-access journal
Subterranean Biology
Published by The International Society for Subterranean Biology

Two new sympatric cave species of *Castellanethes* (Isopoda, Oniscidea, Olibrinidae) from Western High Atlas of Morocco

Soumia Moutaouakil[1,2], Mohamed Boulanouar[1,3], Mohamed Ghamizi[1,2], Josiane Lips[4], Rodrigo Lopes Ferreira[5]

1 *Natural History Museum of Marrakech – Research center, Marrakech, Morocco* **2** *Water, Biodiversity and Climate Change Laboratory, Faculty of Sciences Semlalia, Cadi Ayyad University, Marrakech, Morocco* **3** *Ecole Normale Supérieure of Marrakech, Cadi Ayyad University, Marrakech, Morocco* **4** *Groupe d'Etudes de Biospéologie, Fédération Française de Spéléologie, Lyon, France* **5** *Centro de Estudos em Biologia Subterrânea, Departamento de Ecologia e Conservação, Universidade Federal de Lavras, Lavras, MG. CEP 37200–900, Minas Gerais, Brazil*

Corresponding author: Soumia Moutaouakil (soumia.moutaouakil@edu.uca.ac.ma)

Academic editor: S. Taiti | Received 30 September 2022 | Accepted 29 December 2022 | Published 30 January 2023

https://zoobank.org/2914532A-9A22-4756-98F3-7D885262AA44

Citation: Moutaouakil S, Boulanouar M, Ghamizi M, Lips J, Ferreira RL (2023) Two new sympatric cave species of *Castellanethes* (Isopoda, Oniscidea, Olibrinidae) from Western High Atlas of Morocco. Subterranean Biology 45: 17–37. https://doi.org/10.3897/subtbiol.45.95845

Abstract

Two new sympatric isopod species of the genus *Castellanethes* (Olibrinidae) are described from caves located in the Western High Atlas of Morocco. Both species present troglomorphic traits, such as the absence of body pigmentation and eyes and are, therefore, considered cave-dwelling species (troglobitic). *Castellenethes ougougensis* **sp. nov.** was found in five caves, while *C. ighousi* **sp. nov.** is an amphibious species found in only two caves, which also harbour populations of *C. ougougensis* **sp. nov.** Additionally, notes on their habitats are provided, as well as a discussion on their conservation status.

Keywords

cave, cave-dwelling, *Castellanethes ighousi*, *Castellanethes ougougensis*, Morocco

Copyright *Soumia Moutaouakil et al.* This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Introduction

Globally, the terrestrial isopod richness is represented by 3,984 species (Campos-Filho and Taiti 2021). In Morocco, 81 species of Oniscidea have been recorded, belonging to 14 families: Ligiidae with one species in one genus (*Ligia*); Tylidae with one species in one genus (*Tylos*); Trichoniscidae, with six species in four genera (*Finaloniscus*, *Haplophthalmus* and *Graeconiscus* – one sp each, *Trichoniscus* – three spp); Olibrinidae with one species in one genus (*Castellanethes*); Detonidae with one species in one genus (*Armadilloniscus*); Halophilosciidae with two species in two genera (*Halophiloscia* and *Stenophiloscia* – one sp each); Philosciidae, with three species in three genera (*Anaphiloscia*, *Ctenoscia* and *Paractenoscia* – one sp each); Stenoniscidae with one species in one genus (*Stenoniscus*); Spelaeoniscidae, with nine species in four genera (*Atlantoniscus* and *Barbarosphoera* – one sp each, *Marghreboniscus* – two spp and *Spelaeoniscus* – five spp); Platyarthridae, with four species in two genera (*Platyarthrus* – three spp and *Trichorhina* – one sp); Bathytropidae with one species in one genus (*Bathytropa*); Armadillidae with one species in one genus (*Armadillo*); Porcellionidae, with 43 species in six genera (*Porcellio* – 25 spp, *Porcellionides* – nine spp, *Soteriscus* – four spp, *Agabiformius* – two spp, *Lucasius* – two spp and *Leptotrichus* – one sp); and Armadillidiidae, with seven species in two genera (*Armadillidium* – five spp, *Eluma* – two spp). (Schmalfuss 2003; Schmidt and Leistikow 2004; Montesanto et al. 2011; Taiti and Rossano 2015; Garcia et al. 2020).

Although biospeological investigations started in Morocco in the 19th century with the description of two cave beetles by Dieck (1869) (*Geocharis messiniana* and *Crypharis robusta*), only three troglobitic isopods have been recorded since then: the Olibrinid *Castellanethes soloisensis* (Vandel, 1959) from Goran Cave, located in Cape Beddouza near the City of Safi in Central Morocco, the Philoscid *Paractenoscia cavernicola* Taiti & Rossano, 2015 and the Trichoniscid *Graeconiscus gevi* Garcia, Miralles-Núñez & Pérez Fernández, 2020, both from Ghar Knadel Cave, located in the north of Morocco near Laou River.

Caves of the Tamri-Tamraght Basin in the Western High Atlas, were subject to several investigations for years in term of biodiversity studies. Therefore, several species from other groups have been described; the linyphiid spider *Lessertia barbara* (Simon, 1884), the dysderid spider *Dysdera drescoi* Ribera, 1983, the liocranid spider *Agraecina agadirensis* Lecigne, Lips, Moutaouakil & Oger, 2020, the pholcid spider *Maghreba kahfa* Huber, 2022, the carabid beetles *Antoinella fadriquei* Mateu & Escolà, 2006 and *Siagona taggadertensis* Juger & Faille, 2011, the staphylinid beetles *Domene cantonsi* Espanol, 1972 and *Apteranillus bichaini* Perreau & Faille, 2012 and the paradoxosomatid millipede *Jeekelosoma heptarachne* Enghoff & Reboleira, 2019. However, no cave-dwelling isopod has been described to date from this region.

The following work provides a description of two new species of troglobitic Oniscidea from the Western High Atlas (Tamri-Tamraght Basin, Agadir Ida Outanane area), both belonging to the genus *Castellanethes* Brian, 1952. The two species described herein are the first cave-restricted isopods described for this region. In addition, notes on their habitats are provided, along with a discussion on their conservation status.

Materials and methods

Seven limestone caves located in the Tamri Basin (Western High Atlas) were sampled, five of which are located near the Talmat River: the Chauve-souris Cave (30°36'46.40"N, 9°28'01.63"W), the Imi Ougoug Cave (30°36'44.24"N, 9°28'01.56"W), the Ghar Sghir Cave (30°36'35.39"N, 9°28'09.26"W), the Ifri N'Tyaline Cave named also Ifri N'Talmat Cave (30°35'59.20"N, 9°28'56.78"W) and the Ifri Taghrart Ounakrim Cave (30°35'29.44"N, 9°30'56.95"W). The two other localities are the Win Timdouine Cave (30°40'49.75"N, 9°20'40.66"W) and the Tigmi N'Dou Akkal Cave (30°45'34.60"N, 9°25'06.96"W) (Fig. 1).

Specimens were collected with a paintbrush and preserved in 96% ethanol. The collected specimens were dissected in the laboratory for morphological observations. The dissected parts were clarified by a solution of lactic acid and mounted on slides using Hoyer's solution (Anderson 1954). Drawings were performed using a *camera lucida* coupled with an Olympus CHA microscope. Some specimens were dried in an alcoholic series for the analysis of morphological structures using the scanning electron microscope Hitachi TM4000. The type material is deposited in the Biospeological collection of the Natural History Museum of Marrakech, Cadi Ayyad University, Morocco.

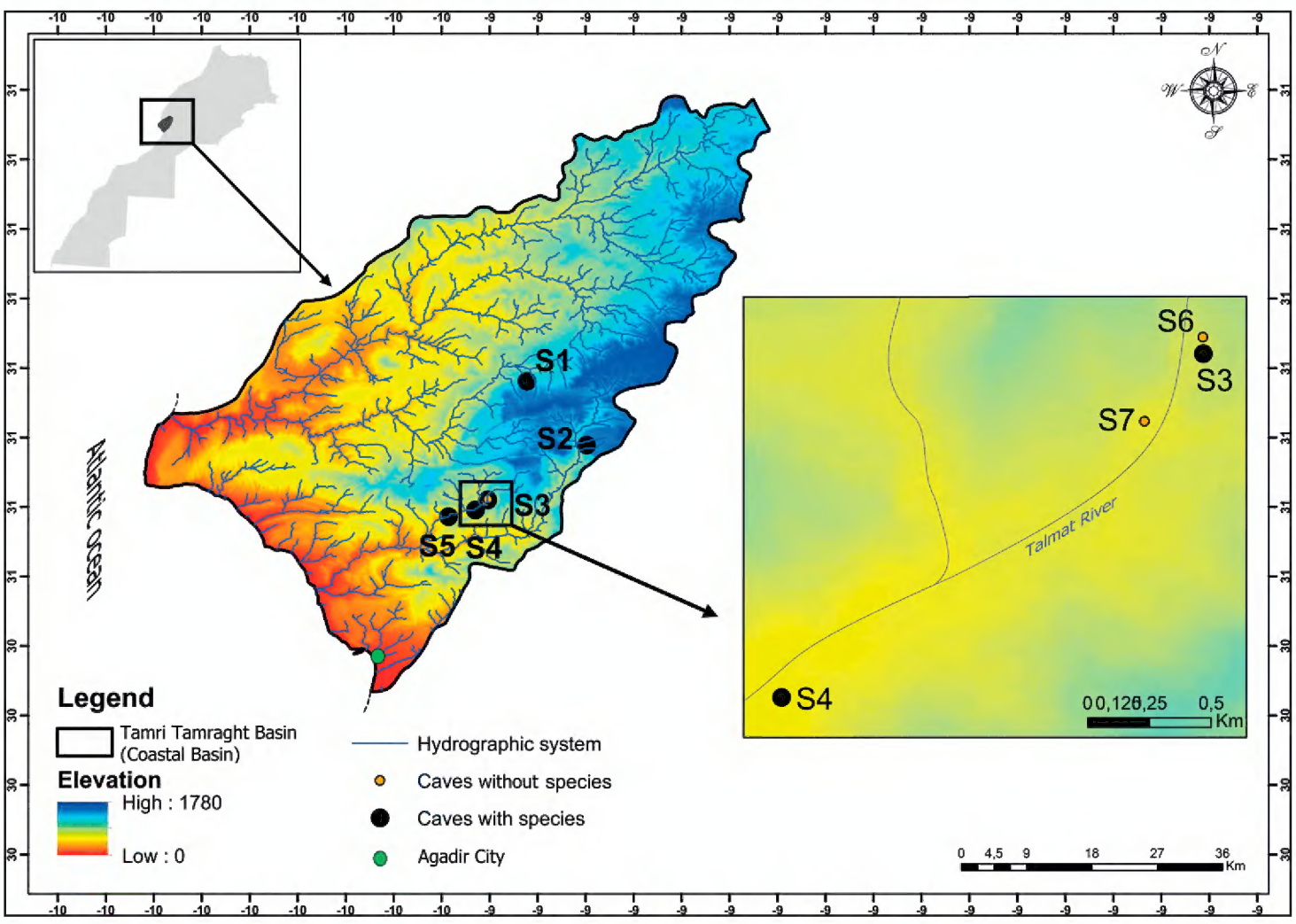

Figure 1. Location of the seven caves prospected for the study of troglobitic isopods in the Tamri Basin; (S1) Tigmi N'Dou Akkal; (S2) Win Timdouine; (S3) Imi Ougoug; (S4) Ifri N'Tyaline; (S5) Taghrart Ounakrim; (S6) Chauve-souris Cave; (S7) Ghar Sghir.

Physico-chemical parameters were measured using a HI98194 portable probe and a HI9564 portable thermohygrometer. The temperature and humidity of the entrance of the cave and the right strand were measured on 20/04/2022. Water temperature, dissolved oxygen and conductivity were measured on 20/04/2016 and on 20/04/2022.

Results

Troglobitic Oniscidea were only found in five caves: Imi Ougoug, Ifri N'Tyaline, Win Timdouine Cave, Taghrart Ounakrim Cave and Tigmi N'Dou Akkal Cave. Hence, no specimens were observed in Chauves-souris and Ghar Sghir Caves (Fig. 1).

Taxonomy

Family Olibrinidae Budde-Lund, 1913
Genus *Castellanethes* Brian, 1952

Remarks. This genus includes five known species: *C. sanfilippoi* Brian, 1952 from Italy; *C. velox* (Vandel, 1955) from Lebanon; *C. soloisensis* (Vandel, 1959) from a Moroccan cave (Goran Cave); *C. insularis* (Taiti, Ferrara & Kwon, 1992) from Indonesia (Togian Islands) and recorded also from the coast of Kenya (Tabasso, near Malindi) by Taiti and Ferrara (2004); and *C. fluviatilis* (Taiti & Ferrara, 2004) from Yemen (Socotra Island).

***Castellanethes soloisensis* (Vandel, 1959)**
Figs 8A, D, 9A, B, 10A, D, G, 11A–C

Trichoniscus soloisensis Vandel, 1959: 162, fig. 3; Cruz 1991: 98, tab.1 (partim); Schmalfuss 2003: 313.
Adoniscus soloisensis: Taiti and Ferrara 2004: 227; Taiti and Gardini 2022: 97, 103, figs IV–V.

Material examined. Morocco • 3 ♂, 2 ♀ (mounted on a slide), Safi-Goran Cave, 32°33'18.17"N, 9°15'09.49"W, alt. 36 m, 14 Dec 2019, Moutaouakil S. leg., MHNM ZAI15.

Remarks. *Castellanethes soloisensis* is the first cave-dwelling isopod described from Morocco. This species was described by Vandel (1959) on the basis of 1 ♂ and 13 ♀ from the Goran Cave. Recently, the species was transferred to the genus *Castellanethes* by Taiti and Gardini (2022), based on the characters present in a female syntype from the same cave. So far, *C. soloisensis* seems to be endemic to the karst area near the City of Safi. Cruz (1991) recorded this species from several caves in Morocco: four caves near the city of Azilal-Central High Atlas (Ifri N'Touaya Cave, Ifri Bernat Cave, Ifri Bouylg-Maine and Sima Aurat Cave), one cave near the City of Agadir-Western High

Atlas (Wit Tamdoun which corresponds to Win Timdouine Cave) and Goran Cave. Most probably, the specimens from caves of the Central High Atlas do not belong to *C. soloisensis*, while specimens from Win Timdouine Cave probably correspond to *C. ougougensis* sp. nov. described below. Re-examination of the collection studied by Cruz (1991) is needed for a correct identification.

Castellanethes ougougensis **Moutaouakil & Boulanouar, sp. nov.**
https://zoobank.org/B2EE7107-4D7B-46C2-99C5-1668C3688183
Figs 2–4, 8B, E, 9C, D, 10B, E, H, 11D–F, 12H

Material examined. ***Holotype*:** Morocco • 1 ♂ (mounted on a slide), Agadir-Imi Ougoug Cave, alt. 773 m, 29 Dec 2019, Moutaouakil S. leg. MHNM ZAI01. ***Paratypes*:** Morocco • 2 ♀, Imi Ougoug Cave, 26 Feb 2020, Moutaouakil S. leg., MHNM ZAI03 and MHNM ZAI04 • 1 ♂, Ifri N'Tyaline Cave, 27 Oct 2019, Lips J. leg., MHNM ZAI05 • 1 ♂, Win Timdouine Cave, 31 Oct 2019, Moutaouakil S. leg., ZAI06 • 1 ♂, Taghrart Ounakrim Cave, 04 Nov 2019, Moutaouakil S. leg., MHNM ZAI07 • 1 ♂, Tigmi N'Dou Akkal Cave, 25 Feb 2020, Moutaouakil S. leg., MHNM ZAI08.

Diagnosis. Telson with double-rounded tips. Antennula with eight petaliform aesthetascs. Antennal flagellum with six articles. Molar penicil of mandible with two plumose setae. Male pleopod 1 endopod with four wide scales at apex inner margin. Male pleopod 2 endopod thick and about 1.5× as long as exopod.

Description. Maximum body length: ♂ 5 mm, ♀ 6 mm. Body outline as in Fig. 2A. Colourless, dorsal surface tuberculate with tubercles arranged as follows: cephalon with four rows of tubercles; pereonite 1 with three rows of tubercles; pereonites 2–7 with two rows; pleonites 1 and 2 with one row of tubercles each, pleonites 3–5 and telson smooth, the latter about four times wider than long (Fig. 10B). Pleon narrower than pereon. Antennula with three articles (Fig. 8E), second article with one row of short setae on outer margin, third article with one row of eight petaliform aesthetascs along outer margin. Antenna long and slender (Fig. 8B), flagellum of six articles. Mandible with molar penicil consisting of two branches (Fig. 9C, D), basal one more than twice as long as the other; left mandible with 2+1 penicils, right with 1+1 penicils. Maxillula (Fig. 2B, C) outer endite with 12 simple teeth and one long seta, inner branch without setae, penicils or spines. Maxilla (Fig. 2D) rounded and covered with thin setae and one row of thick setae. Maxilliped (Fig. 2E) endite with long apical penicil; epipodite bearing fringe of thin setae on outer margin. Pereopods with long plumose dactylar seta (Fig. 3A–G). Uropods (Fig. 10B) with protopod slightly longer than wide; exopod bearing one row of scales on inner margin; endopod wider and longer than exopod.

Male. Pleopod 1 (Figs 4A, 10E) endopod with distal part pointed bent inwards, bearing four large transversal scales on the inner side; exopod triangular with no scale-setae (Fig. 4B). Pleopod 2 (Figs 4C, 10H) endopod thick and about 1/5 as long as exopod; exopod with one to two setae on apex (Fig. 4D).

Etymology. The name refers to the cave where the specimens were found first: Imi Ougoug Cave.

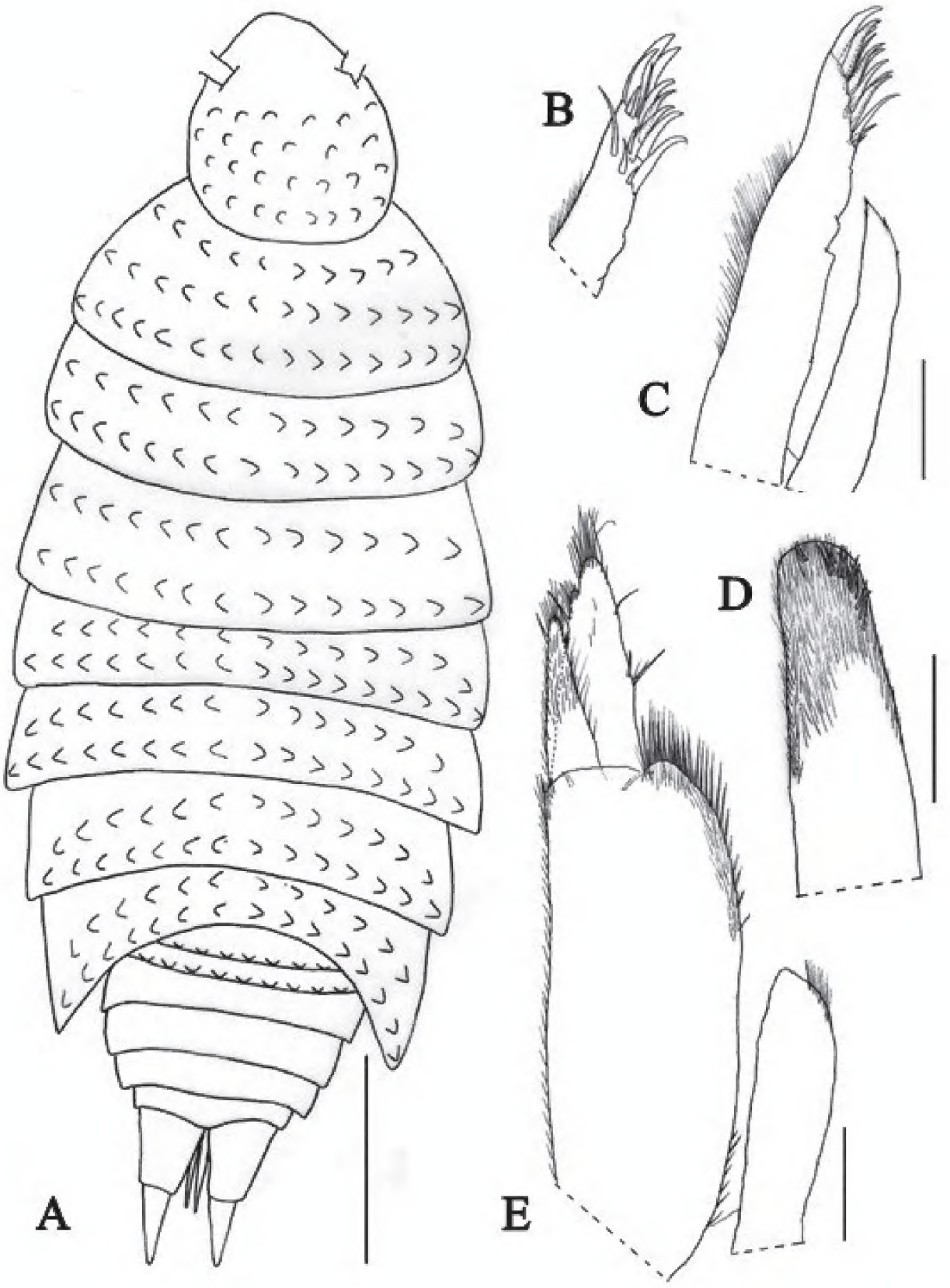

Figure 2. *Castellanethes ougougensis* sp. nov. ♂ specimen from Imi Ougoug Cave **A** adult specimen, dorsal view **B, C** maxillula **D** maxilla **E** maxilliped. Scale bars: 1 mm (**A**); 0.1 mm (**B–E**).

Castellanethes ighousi **Moutaouakil & Boulanouar, sp. nov.**
https://zoobank.org/B309B998-9962-411A-A97B-71E3497AD0C4
Figs 5–7, 8C, F, 9E, F, 10C, F, I, 11G–I, 12F

Material examined. ***Holotype*:** Morocco • 1 ♂ (mounted on a slide), Agadir-Imi Ougoug Cave, alt. 773 m, 22 May 2016, Moutaouakil S. leg., MHNM ZAI02. ***Paratypes*:** Morocco • 2 ♀, Imi Ougoug Cave, 29 Dec 2019, Moutaouakil S. leg., MHNM ZAI09 • 1 ♂, Tigmi N'Dou Akkal Cave, 25 Feb 2020, Moutaouakil S. leg., MHNM ZAI10.

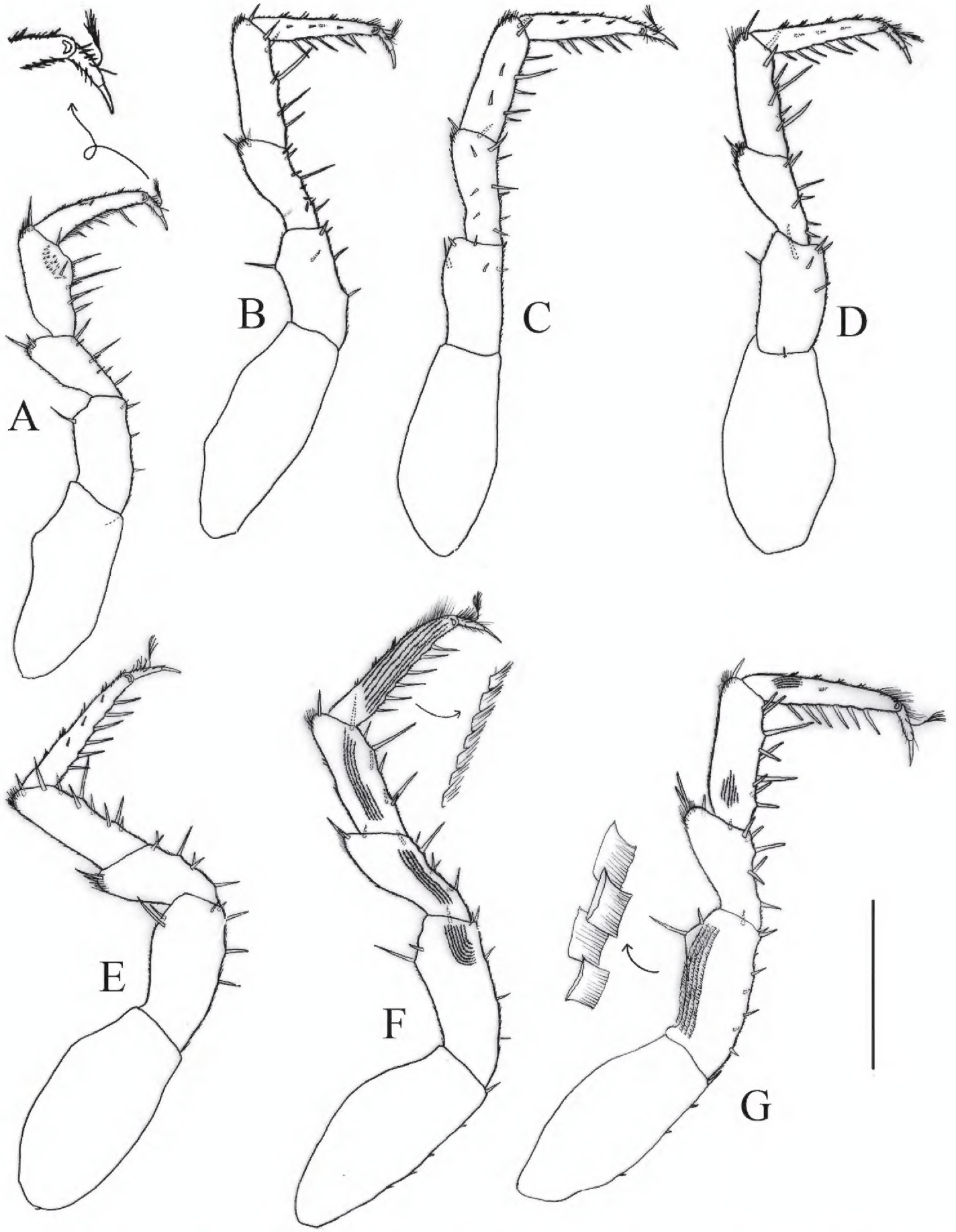

Figure 3. *Castellanethes ougougensis* sp. nov. ♂ specimen from Imi Ougoug Cave **A** pereopod 1 **B** pereopod 2 **C** pereopod 3 **D** pereopod 4 **E** pereopod 5 **F** pereopod 6 **G** pereopod 7. Scale bar: 0.5 mm.

Diagnosis. Telson with double-rounded tips. Antennula with three petaliform aesthetascs. Antennal flagellum with five articles. Molar penicil of mandible with two plumose setae. Male pleopod 1 endopod with four scales at the apex inner margin. Male pleopod 2 endopod stout with distal part tapering.

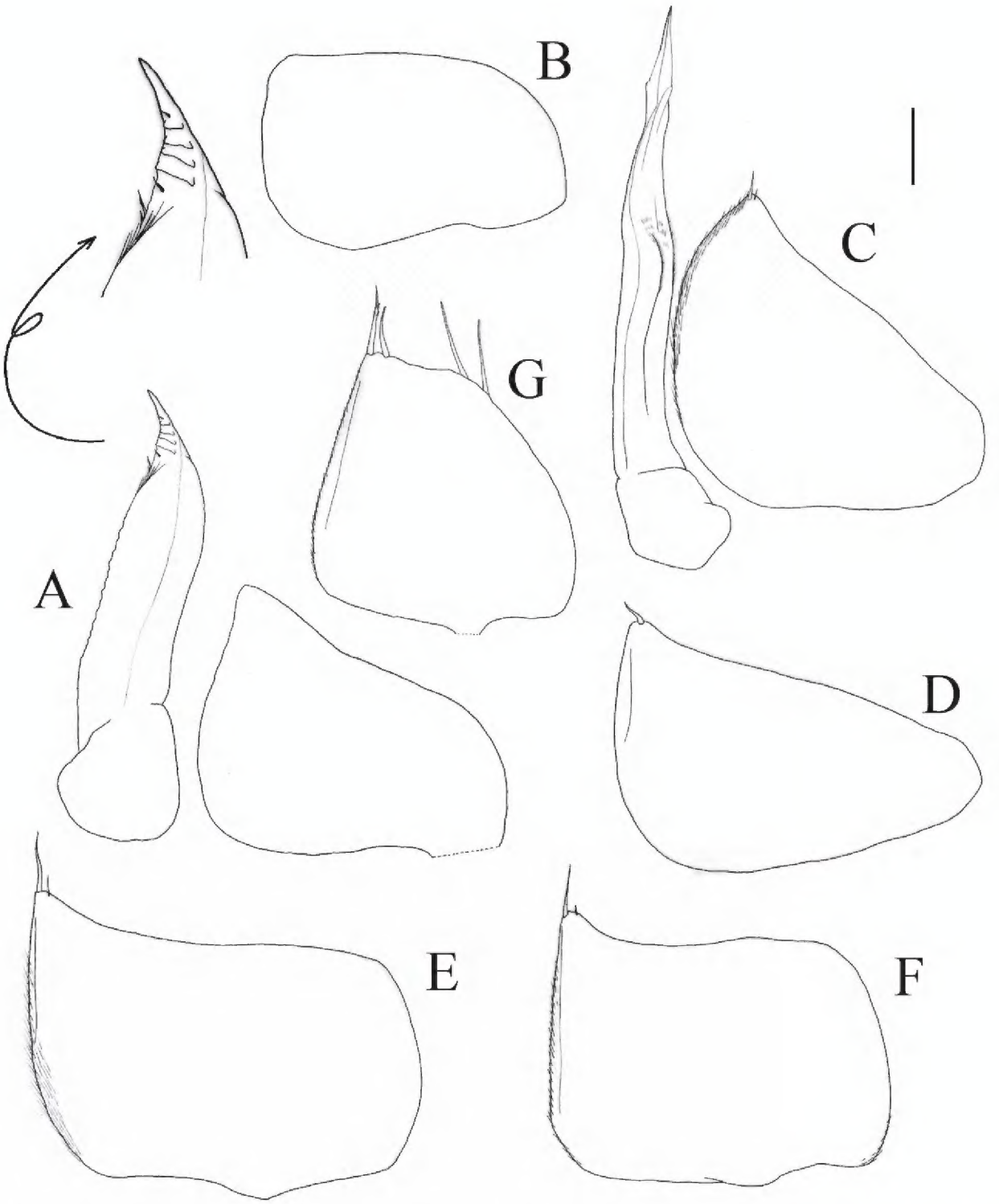

Figure 4. *Castellanethes ougougensis* sp. nov. from Imi Ougoug Cave **A** male pleopod 1 **B** female pleopod 1 exopod **C** male pleopod 2 **D** female pleopod 2 exopod **E** male pleopod 3 **F** male pleopod 4 **G** male pleopod 5. Scale bar: 0.1 mm.

Description. Maximum body length: ♂ and ♀ 8 mm. Body outline as in Fig. 5A. Colourless body, dorsal surface slightly granulated. Pleon narrower than pereon. Telson reduced, about three times wider than long (Fig. 10C). Antennula with three articles; third article with three petaliform aesthetascs (Fig. 8F). Antenna long; articles of peduncle with small-scale setae and simple setae, flagellum of five articles (Fig. 8C). Mandible with molar penicil consisting of two branches (Fig. 9E, F). Maxillula (Fig. 5B) outer endite with nine to ten simple teeth, two or three serrated setae and one long simple seta; inner endite with one row of small simple setae on inner distal margin. Maxilla (Fig. 5C) rounded and covered with many thin simple setae and a row of thick setae. Maxilliped (Fig. 5D) endite with long apical penicil; epipo-

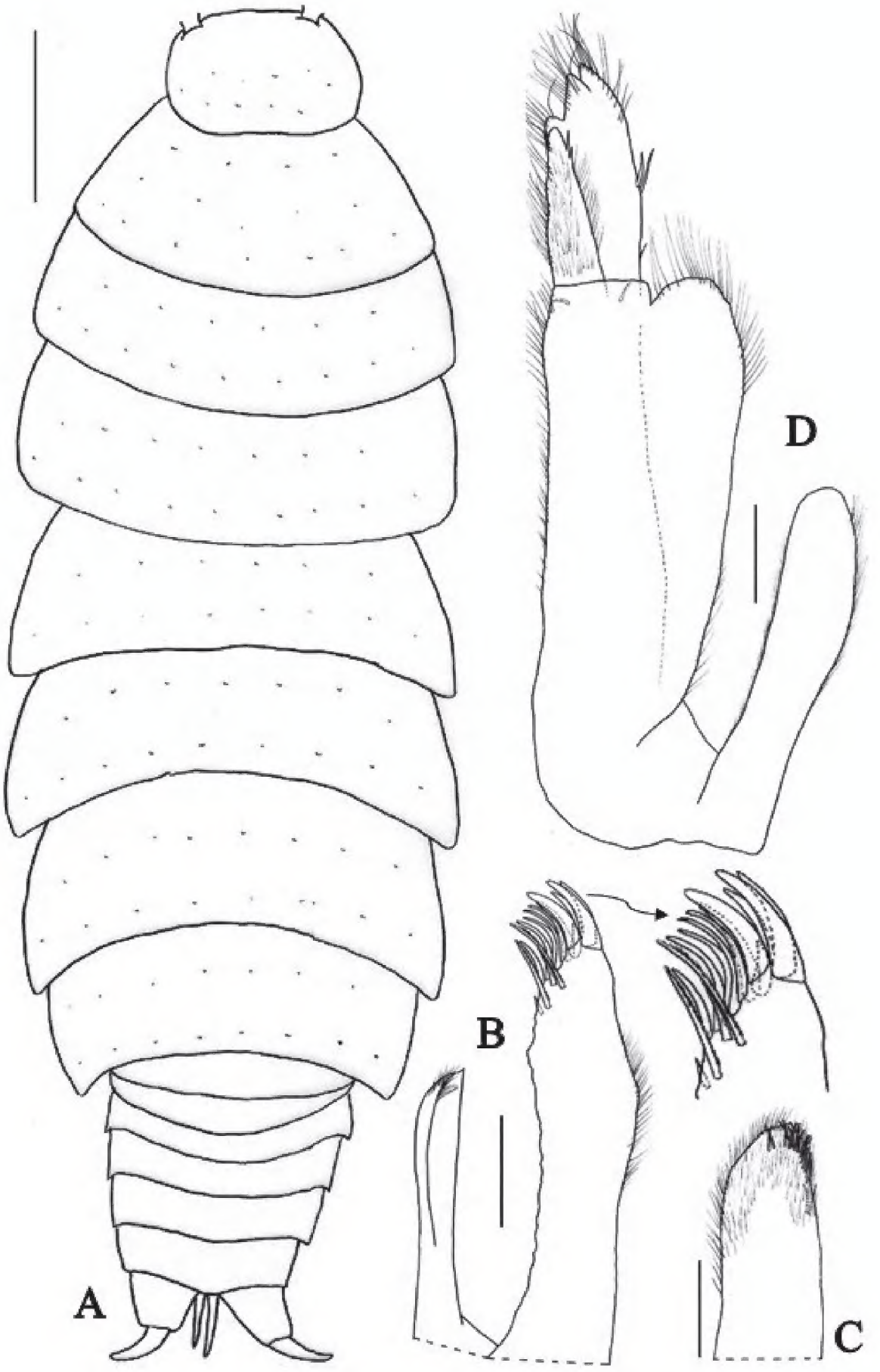

Figure 5. *Castellanethes ighousi* sp. nov. ♂ specimen from Imi Ougoug Cave **A** adult specimen, dorsal view **B** maxillula **C** maxilla **D** maxilliped. Scale bars: 1 mm (**A**); 0.1 mm (**B–D**).

dite hairy with a row of elongate setae on distal margin. Dactylar seta bifurcated and plumose. Pereopods increase in size, with pereopod 7 about twice as long as pereopod 1 (Fig. 6A–G). Uropods (Fig. 10C) with protopod wider than long; exopod as thick as endopod, bearing one row of scales on inner margin; endopod bearing many short setae on apex and one long seta.

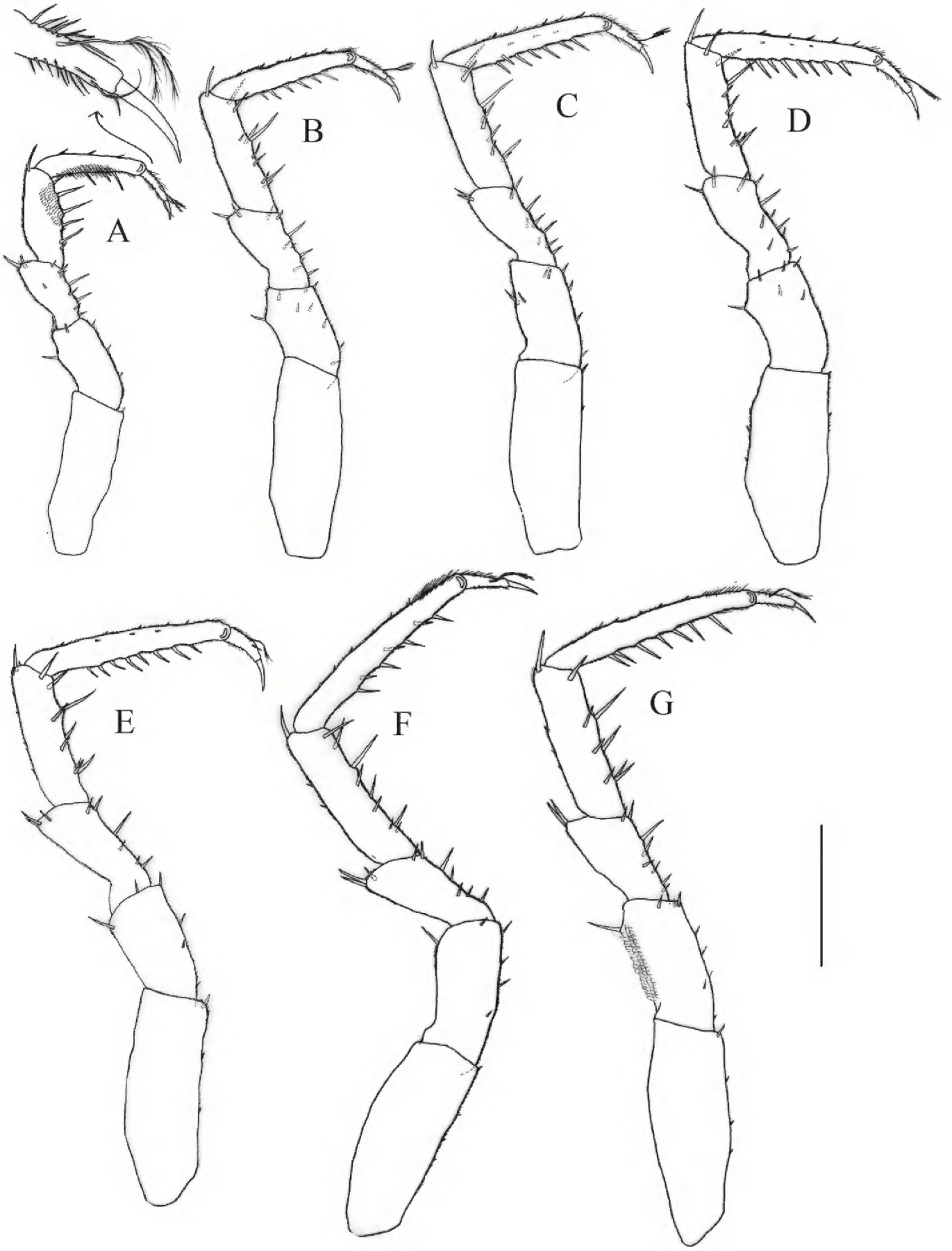

Figure 6. *Castellanethes ighousi* sp. nov. ♂ specimen from Imi Ougoug Cave **A** pereopod 1 **B** pereopod 2 **C** pereopod 3 **D** pereopod 4 **E** pereopod 5 **F** pereopod 6 **G** pereopod 7. Scale bar: 0.5 mm.

Male. Pleopod 1 (Figs 7A, 10F) endopod with pointed tip bent inwards, bearing four scales on inner side; exopod triangular bearing one seta at apex and thin simple setae on inner margin (Fig. 7B). Pleopod 2 (Figs 7C, 10I) endopod bent outwards

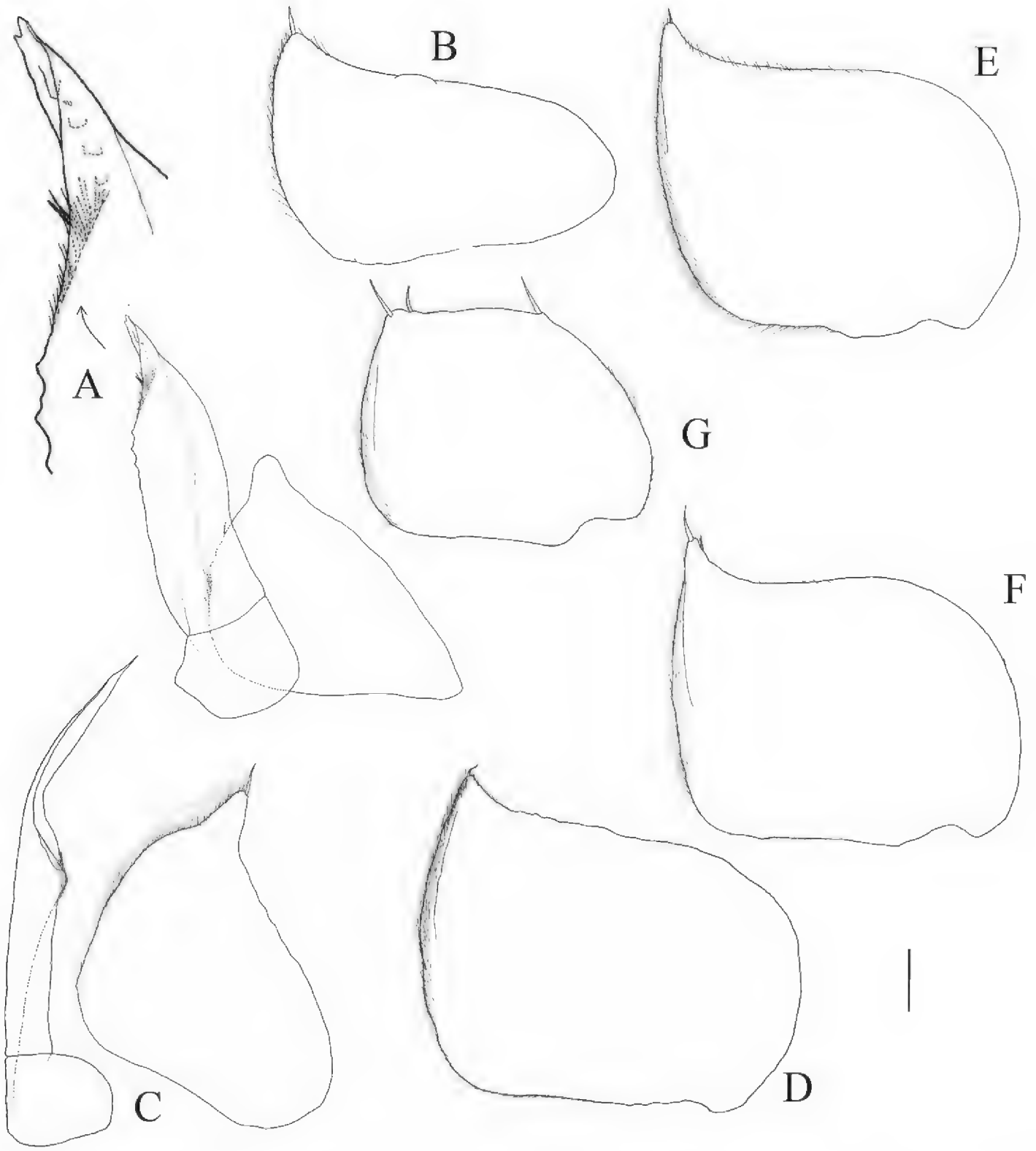

Figure 7. *Castellanethes ighousi* sp. nov. from Imi Ougoug Cave **A** male pleopod 1 **B** female pleopod 1 exopod **C** male pleopod 2 **D** female pleopod 2 exopod **E** male pleopod 3 **F** male pleopod 4 **G** male pleopod 5. Scale bar: 0.1 mm.

with wide proximal half and thin distal part; exopod with small simple setae on inner margin (Fig. 7D).

Etymology. The new species is named after Mr. Ighous Abdelaziz, the speleologist with whom one of the authors (SM) visited Imi Ougoug Cave the first time and who passed away 5 years ago. He was one of the pioneers of speleology in the Agadir region and one of the founders of the Association Sportive de Spéléologie (ASS).

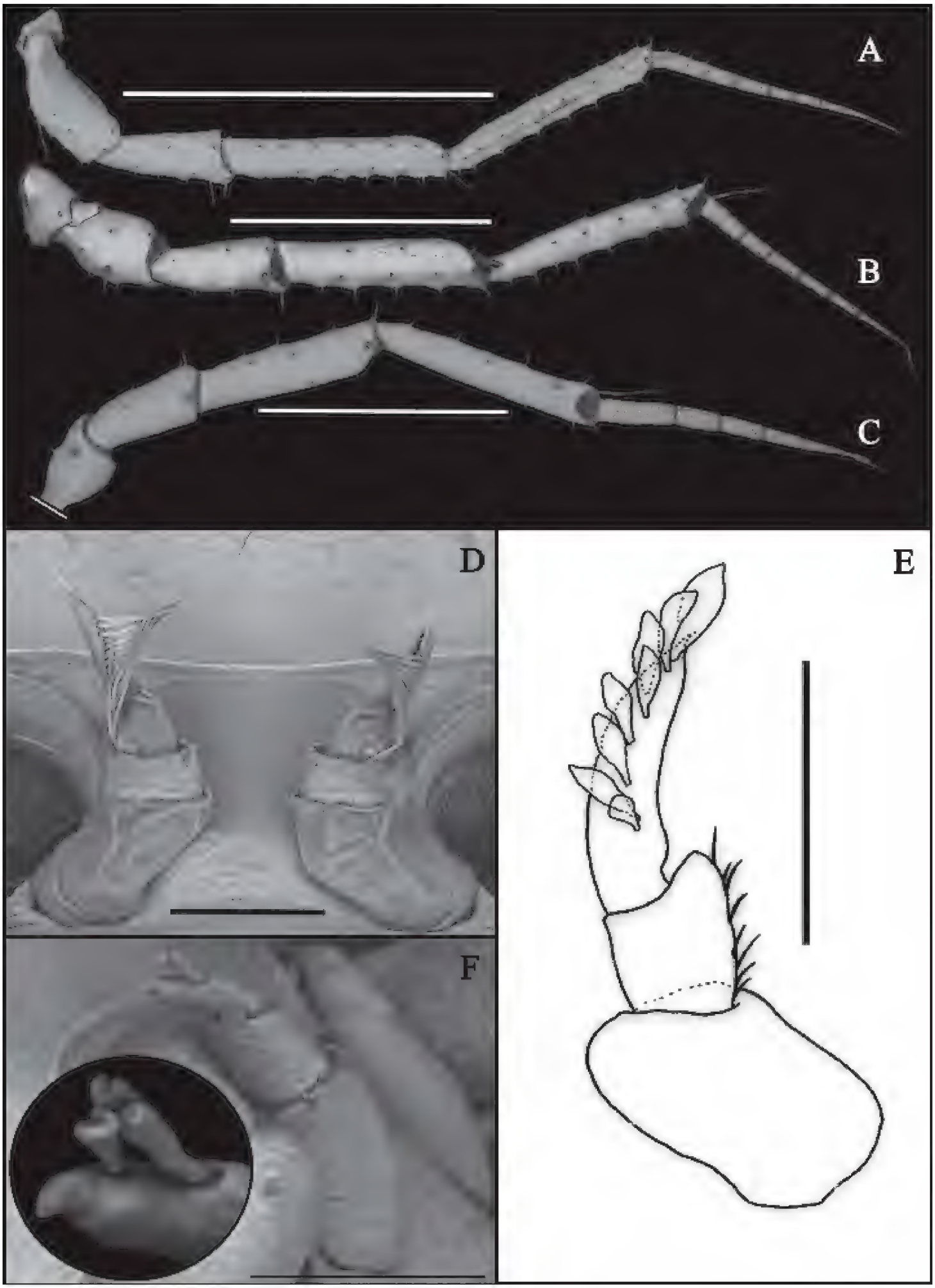

Figure 8. *Castellanethes soloisensis* from Goran Cave **A** antenna **D** antennula. *Castellanethes ougougensis* sp. nov. from Imi Ougoug Cave **B** antenna **E** antennula. *Castellanethes ighousi* sp. nov. from Imi Ougoug Cave **C** antenna **F** antennula. Scale bars: 1 mm (**A**); 500 µm (**B, C**); 100 µm (**D–F**).

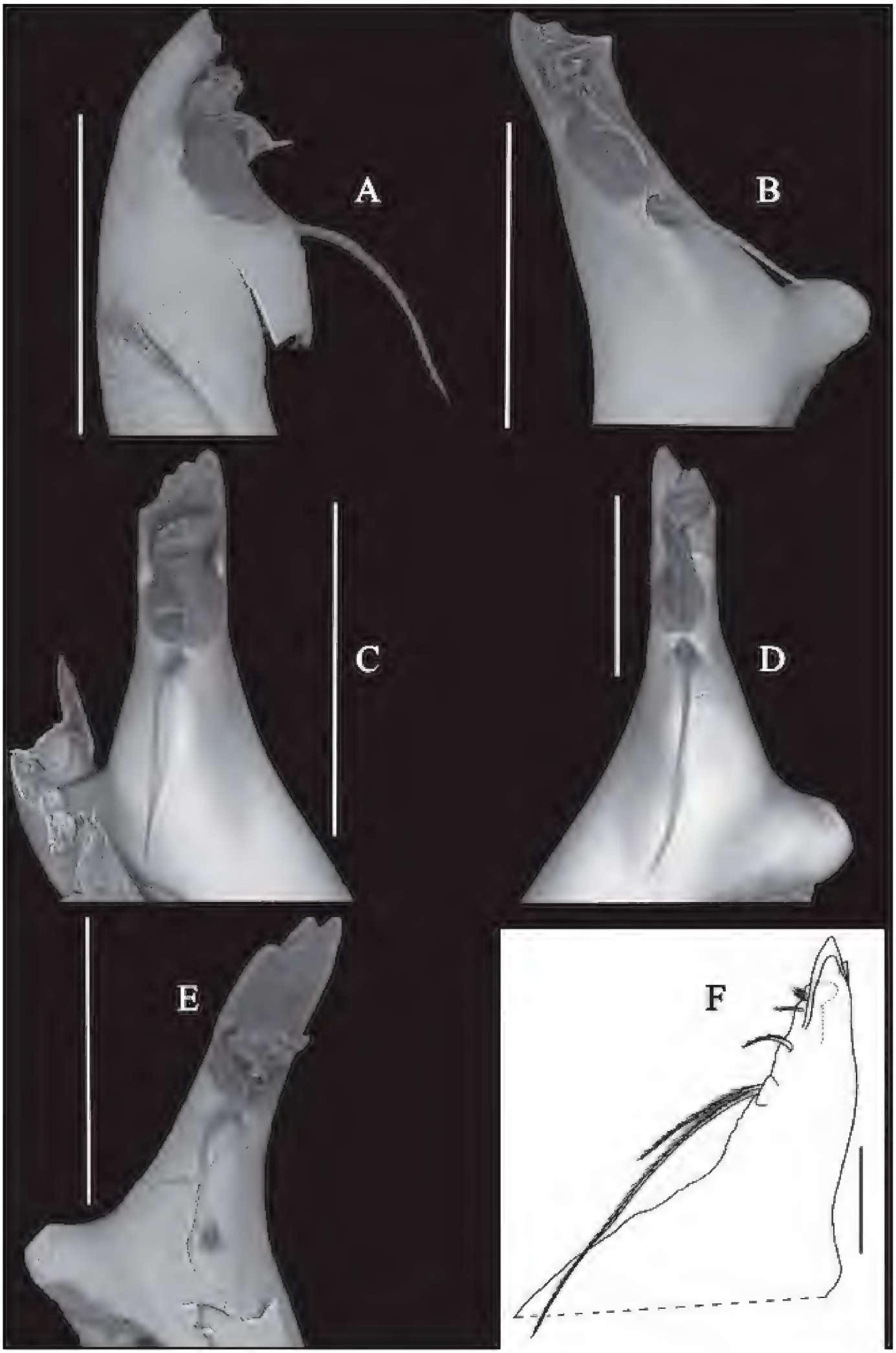

Figure 9. *Castellanethes soloisensis* from Goran Cave **A** left mandible **B** right mandible. *Castellanethes ougougensis* sp. nov. from Imi Ougoug Cave **C** left mandible **D** right mandible. *Castellanethes ighousi* sp. nov. from Imi Ougoug Cave **E** left mandible **F** right mandible. Scale bar: 200 µm (**A–F**).

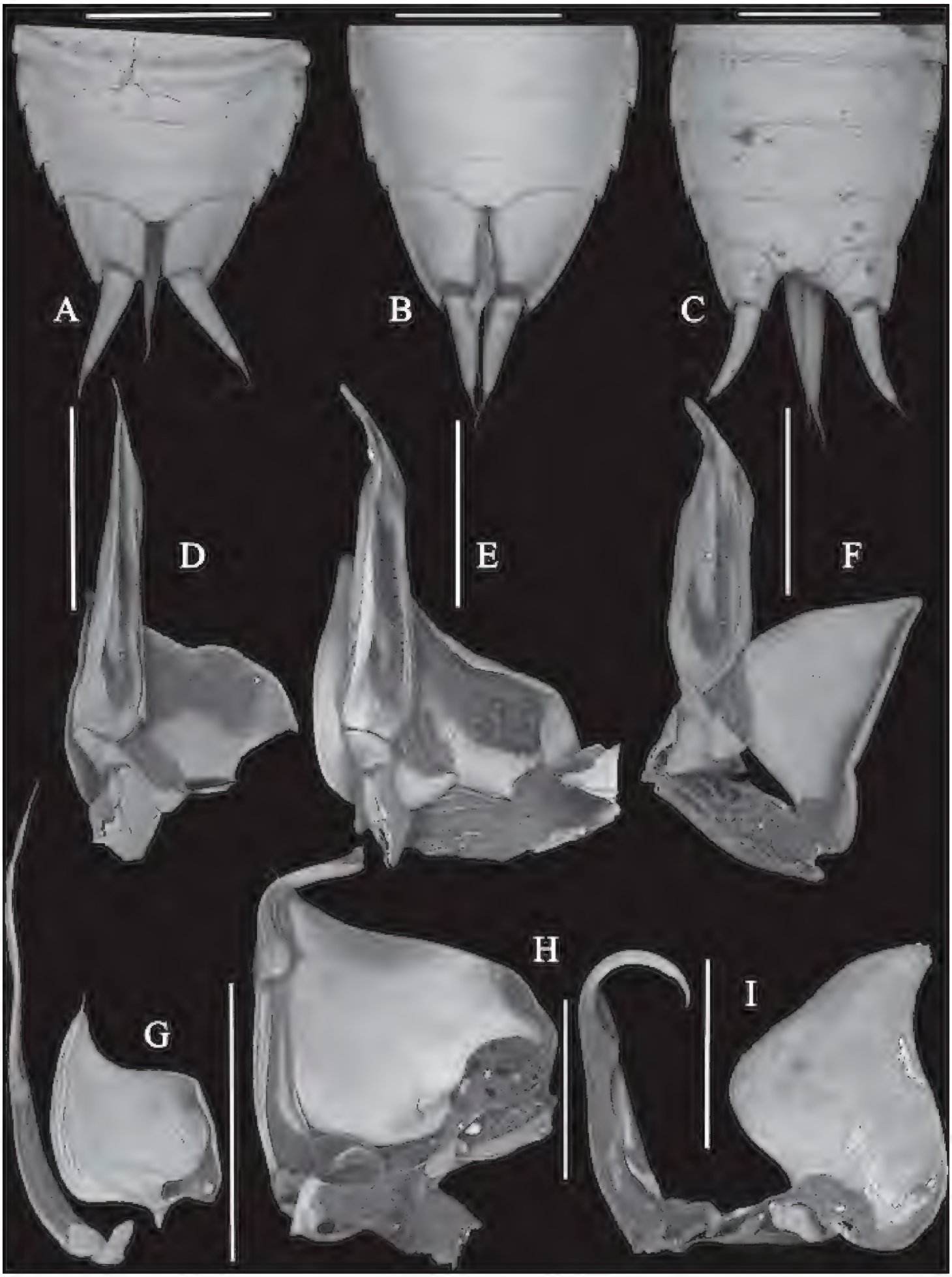

Figure 10. *Castellanethes soloisensis* from Goran Cave **A** telson + uropods **D** male pleopod 1 **G** male pleopod 2. *Castellanethes ougougensis* sp. nov. from Imi Ougoug Cave **B** telson + uropods **E** male pleopod 1 **H** male pleopod 2. *Castellanethes ighousi* sp. nov. from Imi Ougoug Cave **C** telson + uropods **F** male pleopod 1 **I** male pleopod 2. Scale bar: 500 µm (**A, C, G**); 400 µm (**B**); 300 µm (**D, F, I**); 200 µm (**E, H**).

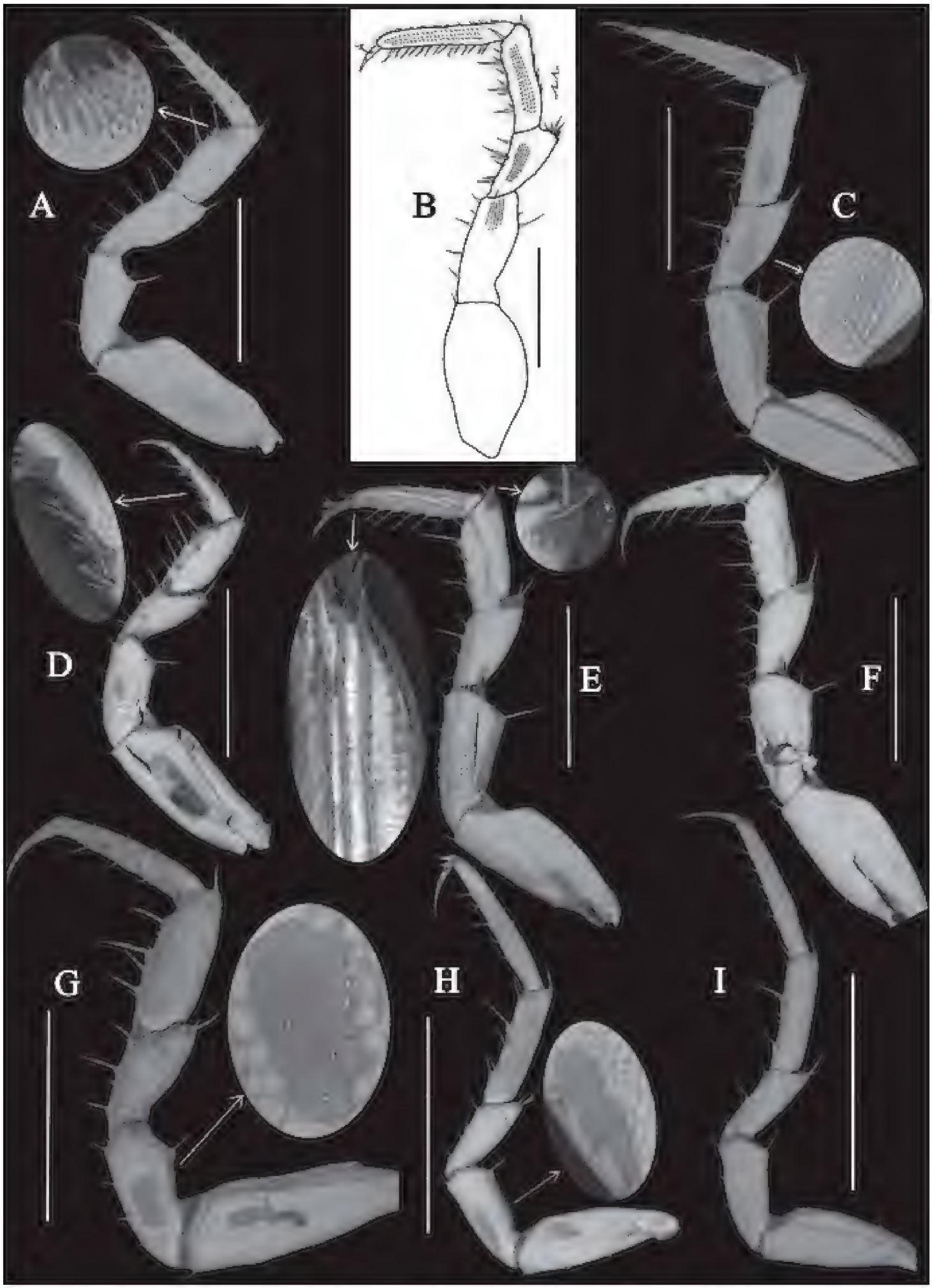

Figure 11. *Castellanethes soloisensis* ♂ specimen from Goran Cave **A** pereopod 1 **B** pereopod 6 **C** pereopod 7. *Castellanethes ougougensis* sp. nov. ♂ specimen from Imi Ougoug Cave **D** pereopod 1 **E** pereopod 6 **F** pereopod 7. *Castellanethes ighousi* sp. nov. ♂ specimen from Imi Ougoug Cave **G** pereopod 1 **H** pereopod 6 **I** pereopod 7. Scale bar: 1 mm (**H, I**); 500 µm (**A–G**).

Figure 12. Presentation of the type locality (Imi Ougoug Cave) **A** entrance of the Imi Ougoug Cave **B** Imi Ougoug Cave topography **C** external area at Talmat River **D** aquatic habitat inside Imi Ougoug Cave **E** terrestrial habitat **F** *Castellanethes ighousi* in a pond **G** Scolopendromorpha/isopod's predator **H** *Castellanethes ougougensis.*

Discussion

Castellanethes ougougensis sp. nov. and *C. ighousi* sp. nov. were placed into the genus *Castellanethes* because they possess all the characters defined by Brian (1952) and Taiti and Gardini (2022). They are described as a new species since they are distinguishable from the other five species of the genus.

Castellanethes ougougensis sp. nov. differs from *Castellanethes ighousi* sp. nov. by remarkable tubercles (Fig. 2A) instead of reduced ones on the dorsal surface (Fig. 5A); antennula with one row of eight petaliform aesthetascs on the third article (Fig. 8E) instead of three petaliform aesthetascs (Fig. 8F); antennal flagellum with six articles instead of five (Fig. 8B, C); pereopods 1–7 subequal in length (Figs 3, 11D–F) instead of increasing in size with pereopod 7 about twice as long as pereopod 1 (Figs 6, 11G–I); male pleopods 1 endopod long and thin with pointed tip (Figs 4A, 10E) compared to *C. ighousi* sp. nov. pleopod 1 endopod which is wider and shorter (Figs 7A, 10F); male pleopod 2 endopod styliform and thick (Figs 4C, 10H) instead of having wide proximal half and thin distal part (Figs 7C, 10I); uropods (Fig. 10B) with protopod longer than wide and thin exopod bearing two to three setae on the apex and a row of scales on inner margin, while *C. ighousi* sp. nov. uropod protopod is wider than long and exopod as thick as endopod (Fig. 10C).

The two new species differ from the five known species of this genus by remarkable characters. *Castellanethes soloisensis* is characterised by an antennula with spiniform aesthetascs (Fig. 8D), antennal flagellum with eight articles (Fig. 8A), male pleopod 1 endopod with nine scales at the apex inner margin (personal observation) and male pleopod 2 endopod styliform and more than twice as long as exopod (Fig. 10G). *Castellanethes velox* has a mandible with molar penicil consisting of one plumose seta, a telson with triangular distal part and antenna with four flagellar articles. *Castellanethes insularis* shows presence of eyes and mandible with molar penicil consisting of four setae. *Castellanethes fluviatilis* possesses antennula with only two thickset aesthetascs. Finally, *Castellanethes sanfilippoi* is distinguished by the antennal flagellum with four articles and pleopod 2 endopod longer and thickset.

Habitat

Imi Ougoug is a limestone cave, also known as "Ifri Ouado" which means "the blowing cave" in Amazigh, a name that was given by local people due to the air current that comes out of it. It is also known as "Grotte des Araignées", which means "spider cave" in French, referring to the large number of harvestmen found inside. This cave is located 43 km northeast of Agadir City, at the bottom of a cliff overlooking the Talmat River. It has a small entrance with a narrow zig-zag passage that splits after reaching 10 m from the entrance and leads on the right to the southern passage of the Imi Ougoug Cave. This passage, which consists of a sinuous path with alternating dry areas and ponds, ends 435 m from the entrance on a siphoning lake (Fig. 12B) (MET 1981).

The two Isopoda species were observed on this strand; *Castellanethes ougougensis* sp. nov. (Fig. 12H) was mainly observed in terrestrial environments, while *Castellanethes ighousi* sp. nov. (Fig. 12F) seems to be aquatic. Their co-occurrence in this cave can be explained by the different habitats they occupy, which contributes to a low niche overlap and reduced (if any existing) interspecific competition (Taiti et al. 2018).

This part of the cave, inhabited by the two species, is characterised by a temperature of 20.8 °C and a humidity reaching 91.2% compared to the entrance zone which is drier and colder (humidity = 73% and temperature = 17.1 °C). The average water temperature is 22.5 °C, dissolved oxygen is 4.51 mg/l (60.9%), pH is 7.04 and conductivity is 360 µS/cm.

As this cave was subject to flooding in the past by the Talmat River, it received a lot of debris from the outside. However, since this river has been dry for a number of years, the main source of organic matter for the isopods is probably wood fragments observed in some areas, bat guano and microbial communities. This cave is connected with the "Chauves-souris" Cave which hosts a large colony of bats.

Notes on conservation

Several other troglobitic and troglomorphic species inhabit the Imi Ougoug Cave: the liocranid spider *Agraecina agadirensis*, the staphylinid beetle *Apteranillus bichaini* and the cirolanid isopod *Typhlocirolana haouzensis* Boutin, Boulanouar, Coineau & Messouli, 2002 (personal observation), the latter has been recorded in many regions in Morocco (in the south-eastern regions of the High Atlas, in the western area and in further northern regions (the Peri-Rifian area)), but never from caves in upstream areas of the Atlas Mountains (Boutin et al. 2002). However, this stygobitic species has been observed in the left passage of Imi Ougoug Cave at an elevation of 800 m.

Other troglobitic species not yet described have also been observed: a japygid (Diplura), a centipede (Scolopendromorpha), a dysderid spider and many paradoxosomatid specimens. Some of these species are potential predators of the isopods (Pagés 1951; Arnedo et al. 2007).

The small distributional range of these troglobitic species, their physiological specialisation and the simplified ecological communities to which they belong, imply a greater vulnerability of these species and a higher risk of trophic web disruption. Considering their inability to modify their distribution in response to eventual habitat disturbances, such species may be considered threatened, especially when taking into account alterations arising from climate change (Mammola and Isaia 2017). In addition, this Cave has become the main destination for local associations and tourist groups (Lecigne and Moutaouakil 2021). Moreover and given the cave morphology, the different habitats cannot be avoided while progressing inside. Therefore, the protection of this cave ecosystem through legislative acts is highly recommended.

The lack of studies on troglobitic isopods in Morocco leads to a deficiency regarding the actual biodiversity and distribution of this group. Therefore, quantifing

the threats that endanger their existence is not currently an easy task. This study is a contribution to the knowledge of this particular group and an enhancement of the knowledge of cave-restricted invertebrate fauna in Morocco.

Acknowledgements

The authors would like to thank Stefano Taiti for helping in the identification, Association Sud des Amateurs de la Nature and Association Speleologique Agadir for their help with sampling in Agadir region and Bernard Lips for providing pictures of the external area at Talmat River. A special thanks to Maysa Villela Rezende Souza for reviewing the manuscript. We are also thankful to Marconi Souza Silva and Lais Furtado Oliveira from the Center of Studies on Subterranean Biology for their assistance in the fieldwork. RLF also thanks the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq grant n. 308334/2018–3).

References

Anderson LE (1954) Hoyer's solution as a rapid permanent mounting medium for Bryophytes. Bryologist 57: 242–244. https://doi.org/10.2307/3240091

Arnedo MA, Oromi P, Murria C, Macias-Hernandez N, Ribera C (2007) The dark side of an island radiation: systematics and evolution of troglobitic spiders of the genus *Dysdera* Latreille (Araneae: Dysderidae) in the Canary Islands. Invertebrate Systematics 21(6): 623–660. https://doi.org/10.1071/IS07015

Boutin C, Boulanouar M, Couneau N, Messouli M (2002) Biodiversity in the stygobiontic cirolanids (Crustacea: Isopoda) from the Mediteranean Basin. I. A new species of *Typhlocirolana* in Morocco, taxonomic, ecological and bigeographic data. Journal of Natural History 36: 797–817. https://doi.org/10.1080/00222930010028920

Brian A (1952) Intorno a due interessanti e nuovi trichoniscidi (Isopodi terrestri) raccolti dal Sig. Nino Sanfilippo nella Grave di Castellana (Bari) (Crustacea: Isopoda). Bollettino della Società Entomologica Italiana 82: 3–8.

Campos-Filho IS, Taiti S (2021) Oniscidea taxonomy: present and future. Abstract book of the 11th International Symposium on Terrestrial Isopod Biology. Ghent, Spinicornis, 9 pp. https://spinicornis.be/istib2021/

Cruz A (1991) Isópodos terrestres de la colección del Museu de Zoología de Barcelona (Crustacea, Oniscidea). Miscel· lània Zoològica, 81–102.

Dieck G (1869) Beiträge zur subterranen Käterfauna Südeuropas und Maroccos. Berliner Entomologische Zeitschrift 13: 335–360.

Enghoff H, Reboleira AS (2019) The genus *Jeekelosoma* Mauriès, 1985. Moroccan cave millipedes (Diplopoda, Polydesmida, Paradoxosomatidae). European Journal of Taxonomy 523: 1–16. https://doi.org/10.5852/ejt.2019.523

Español F (1972) Un nuevo *Domene* cavernícola de la región de Agadir, Marruecos Sud-Occidental (Coleoptera, Staphylinidae). Miscelánea Zoológica 3(2): 51–54.

Garcia L, Miralles-Núñez A, Pérez-Fernández T (2020) First record of the genus *Graeconiscus* Strouhal, 1940 (Isopoda, Oniscidea, Trichoniscidae) in the Iberian Peninsula with the description of a new troglobitic species. Subterranean Biology 36: 51–61. https://doi.org/10.3897/subtbiol.36.58272

Huber BA (2022) Revisions of *Holocnemus* and *Crossopriza*: the spotted-leg clade of Smeringopinae (Araneae, Pholcidae). European Journal of Taxonomy 795: 1–241. https://doi.org/10.5852/ejt.2022.795.1663

Juger B, Faille A (2011) Remarkable discovery in a cave of south west Morocco: *Siagona taggadertensis* n. sp. (Carabidae: Siagoninae). Annales de la Société Entomologique de France (N.S.) 47: 162–167. https://doi.org/10.1080/00379271.2011.10697708

Lecigne S, Lips J, Moutaouakil S, Oger P (2020) Two new cave-dwelling spider species from the Moroccan High Atlas (Araneae: Liocranidae, Theridiidae). Arachnologische Mitteilungen / Arachnology Letters 60: 12–18. https://doi.org/10.30963/aramit6002

Lecigne S, Moutaouakil S (2021) First description of the male of *Agraecina agadirensis* (Araneae: Liocranidae), an eyeless spider from the Moroccan High Atlas. Arachnologische Mitteilungen / Arachnology Letters 62: 86–89. https://doi.org/10.30963/aramit6210

Mammola S, Isaia M (2017) Spiders in caves. Proceedings of the Royal Society B 284(20170193), 1–10. https://doi.org/10.1098/rspb.2017.0193

Mateu J, Escolà O (2006) El género *Antoinella* Jeannel, 1937 (Coleoptera, Carabidae, Trechinae) tres especies nuevas de Marruecos: *A. espanyoli* sp. n., *A. iblanensis* sp. n. y *A. fadriquei* sp. n. Animal Biodiversity and Conservation 29: 117–121.

MET, Ministère de l'Equipement et des Transports (1981) Inventaire spéléologique du Maroc. Rabat.

Montesanto G, Caruso D, Lombardo BM (2011) A new species and new records of terrestrial isopods from Sicily (Isopoda: Oniscidea). Journal of Natural History 45(31): 1925–1935. https://doi.org/10.1080/00222933.2011.573099

Pagés J (1951) Contributions à la connaissance des Diploures. Bulletin Scientifique de Bourgogne, Suppl. 9: 1–97.

Perreau M, Faille A (2012) Contribution to the phylogeny and systematic of the hypogean Aleocharinae from North Africa (Coleoptera: Staphylinidae). Annales de la Société Entomologique de France (N.S.)48 (1): 81–96. https://doi.org/10.1080/00379271.2012.10697755

Ribera C (1983) Araneidos cavernícolas de Marruecos. I. Publicaciones del Departamento de Zooloologia, Universidad de Barcelona, Facultad de Biología. Barcelona 9: 73–76.

Schmalfuss H (2003) World catalog of terrestrial isopods (Isopoda: Oniscidea). Stuttgarter Beiträge zur Naturkunde, Serie A 654: 1–341.

Schmidt C, Leistikow A (2004) Catalogue of genera of the terrestrial Isopoda (Crustacea: Isopoda: Oniscidea). Steenstrupia 28(1): 1–118.

Simon E (1884) Araneae et Opiliones (Seconde Série). Biospeologica. XV. Archives de Zoologie Expérimentale et Générale (5) 5(2): 49–66.

Taiti S, Ferrara F (2004) The terrestrial Isopoda (Crustacea: Oniscidea) of the Socotra Archipelago. Fauna of Arabia 20: 211–325.

Taiti S, Gardini P (2022) The family Olibrinidae in Italy (Malacostraca Isopoda Oniscidea). Redia 105: 97–105.https://doi.org/10.19263/REDIA-105.22.13

Taiti S, Rossano C (2015) Terrestrial isopods from the Oued Laou basin, north-eastern Morocco (Crustacea: Oniscidea), with descriptions of two new genera and seven new species. Journal of Natural History 49: 33–34. [2067–2138] https://doi.org/10.1080/00222933.2015.1009512

Taiti S, Ferrara F, Kwon DH (1992) Terrestrial Isopoda (Crustacea) from the Togian Islands, Sulawesi, Indonesia. Invertebrate Taxonomy 6: 787–842. https://doi.org/10.1071/IT9920787

Taiti S, Argano R, Marcia P, Scarpa F, Sanna D, Casu M (2018) The genus *Alpioniscus* Racovitza, 1908 in Sardinia: taxonomy and natural history (Isopoda, Oniscidea, Trichoniscidae). In: Hornung E, Taiti S, Szlavecz K (Eds) Isopods in a changing world. ZooKeys 801: 229–263. https://doi.org/10.3897/zookeys.801.24102

Vandel A (1955) Biospeologica LXXV. Mission Henri Coiffait au Liban (1951). 8. Isopodes terrestres. Archives de Zoologie expérimentale et générale 91: 455–531.

Vandel A (1959) Les Styloniscidae et les Trichoniscidae de l'Afrique du nord (Crustacés; Isopodes terrestres). Bulletin du Muséum national d'Histoire naturelle, Paris, 2e Série 31: 159–167.